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Effects of Elevated CO_2 Application on *Tetranychus cinnabarinus* Boisduval (Acari: Tetranychidae) Population and Fruit quality and Yield in Strawberry

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Abstract

The study was performed under strawberry greenhouse between 2007 and 2008. Elevated CO_2 was applied to 3 different strawberry tunnels in doses of 500,700 and 1000ppm in march, april and may, respectively. Effect of the applications on a *Tetranychus cinnabarinus* population, plant yield and quality parameters was studied, with the result that CO_2 application were found not to cause any effect likely to decrease *T. cinnabarinus* population. CO_2 enrichment increased fruit firmness and yield but did not significantly contributed to soluble solid content, titratable acid and pH of the fruit. The best performance of CO_2 enrichment was found to be 700 ppm, which increased yield by 66% in 2007 and %32 in 2008 as compared to control tunnels.

Key words: *Tetranychus cinnabarinus*, CO_2, yield, fruit quality, strawberry.

INTRODUCTION

Strawberry is a very popular berry species, because of its high C vitamin and folic acid content. Widely used in the production of marmalade, cake and fruit juices, its market value gradually increases, thus enabling growers to earn high profits. Turkey ranks high in the output of strawberry in the world and can meet demands of neighboring nations for strawberry [1]. According to data of 2010, 25.434.184 dollar strawberry was exported. Sultanhisar county produces 4.29% of Turkey's strawberry harvest annually (11200 tons) [1].

Fertilization is one of the most important factors to affect yield and quality of strawberry production. Some farmers have insufficient information about which fertilizer is used for strawberry, application time and method, amount of fertilizer, their fertilizer applies is traditional. The same situation applies for practices of pesticides [2]. *Tetrannychus cinnabarinus* Boisduval (Acari: Tetranychidae) is one of the most important pests in the region and control is commonly based on chemical products [3]. The fact that pesticides create negative effects on natural enemies and environment and also lead to residue problems on the fruit has encouraged alternative ways of controlling the pest, one of which is CO_2 enrichment process. This practice has thus far been a method generally used to control warehouse pests. Many authors in the field claim that warehouse pests could be killed using CO_2 of different doses [4-7]. Tripp et al, [8]. found that CO_2 application (1000µl) for 8.1 hours/day minimized number of *Trialeurodes vaporarium* adults captured by yellow sticky traps in tomato greenhouse. Potter et al, [9] found that adults of *Thrips obscuratus* died 6 days after an application of 18% CO_2. Held et al, [10] reported that 99% enriched CO_2 suppressed *Myzus persicae*, *Bemisia* sp.,*Tetranychus urticae* and *Franklinella occidentalis* following the application of 2-8 hours in begonia and chrysanthemum greenhouses. CO_2 enrichment that has been successfully applied to pests is claimed to be able to increase fruit yield as well. Özçelik [11] found that CO_2 enrichment created an increase of a 43% yield in tomato greenhouse. Aguilere et al, [12] reported that increased CO_2 concentrations could lead to rises in weight and width as well as in yield of eggplant fruit. The study aimed to improve both controlling *T. cinnabarinus* and parameters of yield and quality by enriching CO_2.

MATERIAL AND METHODS

The study was performed using Camarosa strawberry cultivar in the trial garden of Sultanhisar Vocational Collage in 2007 and 2008. Trials were conducted under three different high plastic tunnels of 60 m^2 each. CO_2 fertilization in gaseous form was passed through plastic pipes into strawberry tunnels. The amount of CO_2 was automatically controlled by a solenoid valve and applied to tunnel 1, tunnel 2 and tunnel 3 for 500 ppm, 700 ppm and 1000 ppm, respectively. On the other hand, each of the three tunnels was separated in half lengthwise by a transparent nylon cover. CO_2 was applied into the half of the tunnels whereas the other half was not given CO_2 as a control process during the vegetation period. Applications of CO_2 were made from 6 to 8 a.m. (2 h/day) in march, april and may in 2007 and 2008. Amount of CO_2 was measured by a Testo 535 CO_2 analyzer. To prevent phytotoxicity from emerging in the plants, CO_2 application was stopped when greenhouse temperatures exceeded 30°Cin May 11thin 2007 and May 18th in 2008 [11].

Effect of CO_2 on *Tetranycus cinnabarinus*

Sixty leaflets were taken from each plot once a week which were enriched and not enriched by CO_2 every week until the end of the harvest following CO_2 applications.Mite population counts were done using a stereo binocular microscope. No insecticide application was made for controlling pests as long as the vegetation continued. The study was performed according to randomized design with 3 replicates was used in each treatment and year. One-way Anova was used to compare the effectiveness of CO_2 application on the population of *T. cinnabarinus*. Means were compared at P=0.05 (SPSS).

Observation on yield and quality of plants and fruits

Harvested fruits were weighed to calculate yield values and fruit weight per plant according to general yield and months. In addition, fruit length, weight, and width, soluble solid content, pH and titratable acidity were determined as quality criteria in fruits. Twenty fruits were used from each parcel to determine measurable parameters. Soluble solid content was determined by manual refractometer, pH by pHmeter and titratable acidity by titrimetric method.

RESULTS AND DISCUSSION

Effect of CO_2 application on a *Tetranychus cinnabarinus* population

Figure 1 shows population fluctuation in every three tunnel to which CO_2 was applied for *T. cinnabarinus* from planting until harvest. Population density of *T. cinnabarinus* failed to achieve the level of 15 active stages per leaflet,which is economic damage threshold in 2007. *T. cinnabarinus* reached to the maximum level of 3.6 active stages per leaflet in may of 2007. Population of *T. cinnabarinus* exceeded economic injury level (EIL**)** in every parcel in 2008. The highest mean numbers of *T. cinnabarinus* was of 24.6 active stages per leaflet particularly in May in the same year.

It was showed that differences between means of *T. cinnabarinus* populations were not significant considering different CO_2 applications in both years.

As a result, *T. cinnabarinus* population was found not to be directly affected by different CO_2 levels. Although the tunnel enriched by 1000 ppm CO_2 in 2008 showed more *T. cinnabarinus* than in control tunnel, this difference was not

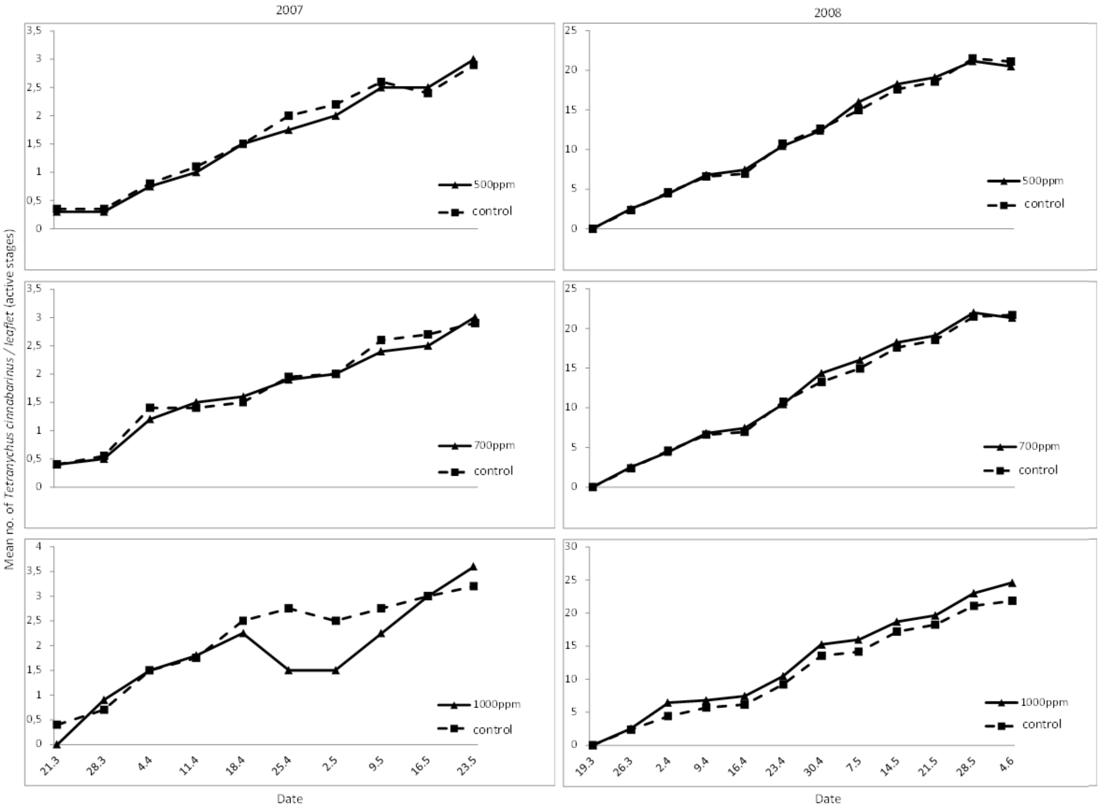

Figure 1. Seasonal populations of *Tetranychus cinnabarinus* on strawberries population density in tunnels enriched by different doses of CO_2 in Sultanhisar, Aydın, Turkey in 2007 and 2008.

Table 1. Total mean number of Tetranychus cinnabarinus on strawberries under different CO2 application in Sultanhisar, Aydın, Turkey in 2007 and 2008 (mean± S.E. per leaflet).

	CO2					
	500ppm	Control	700ppm	Control	1000ppm	Control
2007	1.56±0.30a*	1.62±0.29a	1.70±0.26a	1.74±0.27a	1.83±0.32a	2.10±0.30a
2008	1.15±2.13a	1.14±2.13a	1.18±2.20a	1.15±2.10a	1.25±2.30a	1.11±2.10a

* Numbers followed by the same letter within a line are not significantly different according to Tukey's test (P>0.05).

statistically significant (P>0.05). Different consequences were found from previous studies in which CO_2 was used for controlling mites. For example, Joutei etal, [13] reported that 700 ppm CO_2 enrichment decreased first and second generation larvae of *T. urticae* by 34 and 49%, respectively while Heagle et al, [14] found that CO_2 enrichment the same procedure increased *T. urticae* population. CO_2 enrichment created some changes in the plant content such as serious variable contents of chlorophyll, starch and nitrogen [13]. CO_2 enrichment reduces nitrogen levels of plants. Thus, some herbivore insects can be affected. Their mobility's can be decelerated and therefore captures them to their natural enemies easily.Moreover, this process also causes some insects to change their feeding behaviours. However, it is particularly related to climatic conditions and CO_2enrichment is reported by several papers to increase the population density of some pests [15]. The present study found that CO_2 enrichment did not affect population density of *T. cinnabarinus* directly. Even if CO_2 enrichment increased population density of some pests as reported by some other articles, significant increases in yield and quality of the plant due to the application would be such that they could compensate for the damage caused by the pest.

Effect of CO_2 enrichment on yield

Table 2 shows effect of CO_2 fertilizer of different doses in 2007 and 2008.

It was found that CO_2 enrichment of different doses increased plant yield as compared to controls 500 and 1000 ppm treated. The tunnel in which 700 ppm CO_2 enrichment was applied showed 66% and 32% yield increases as compared to control in 2007 and 2008, respectively.The maximum yield of the application was from the tunnel enriched by 700ppm CO_2 in both years. The rates of yield were 533.05 and 280.11 g/plant in 2007 and 2008 respectively. Although it was expected that the higher CO_2 the more yield would result from the study, the 1000 ppm CO2 enrichment brought about less yield than the 700ppm CO_2 performance. This might suggest that nitrogen was not enough as a necessary plant nutrient to increase growth and yield in the plants enriched by a 1000 ppm CO_2 fertilization. The response of growth to CO_2 enrichment is known to depend on sufficiency of plant nutrient elements [16]. Results from the present study seem consistent with those of previous studies. Bushway and Pritts [17] reported that CO_2 enrichment of 700-1000ppm increased strawberry yield by about 62%.

Fruit quality parameters

Table 3-5 shows total soluble solid content, titratable acidity, pH and fruit firmness.Width, lenght and weight values of fruits from tunnels enriched by 700ppm CO_2 application were observed to be higher than those of other practices (Table 3). However; statistical analyses showed this difference not to be significant (P>0.05), which also applies for pH, total soluble solid content and acidity values (Table 4).

Contrary to the above, a different property can be mentioned about fruit firmness. The tunnels enriched by $C0_2$ fertilization gave higher values of fruit firmness than in controls, which is statistically significant (P<0.05)(Table 5).It was concluded from the 700ppm CO_2 enrichment that fruit firmness was highest by 1.56 lb and therefore important in preventingstrawberry fruit being perishable during transportation.

It followed from the assessments above that CO_2 enrichment led to significant increases in yield. On the other hand, absence of any negative effects of the application on fruit firmness is of great importance in terms of elimination of potential problems during marketing.Therefore, CO_2 enrichment, post-harvest life of strawberries might extend.The fact that CO_2 application to

Table 2. Variations of yield values per plant (g/plant) of CO2 fertilization in months and years.

Application	2007		Total yield per plant	2008		Total yield per plant
	April (g)	May (g)		April (g)	May(g)	
1. tunnel control	231.58 b*	65.68 d	297.26 c	128.67 d	102.90 b	231.57 c
1. tunnel 500 ppm	236.62 b	146.32 b	382,94 c	145.04 b	100.02 b	245.06 b
2. tunnel control	237.20 b	104.93b	342.13 c	114.09 d	92.27 c	206.36 c
2. tunnel1000ppm	258.50 ab	168.00 c	426.50 b	134.73 c	116.74 a	251.47 b
3. tunnel control	253.16 ab	69.44 d	322.60 c	121.19 d	90.83 c	212.02 c
3. tunnel 700 ppm	282.69 a	250.36 a	533.05 a	159.42 a	120.69 a	280.11 a

** Numbers followed by the same letter within a column are not significantly different according to Tukey's test (P>0.05).

Table 3. Effect of CO2 on fruit width, lenght and weight

Application	2007			2008		
	Fruit width (mm)	Fruit lenght (mm)	Fruit weight (g)	Fruit width (mm)	Fruit lenght (mm)	Fruit weight (g)
1. tunnel control	27.29a*	33.42a	14.07 b	26.72a	36.30a	16.60 c
1. tunnel 500 ppm	29.94a	37.26a	17.48 ab	28.31a	38.84a	17.75 b
2. tunnel control	29.72a	36.21a	15.54 b	24.51a	38.29a	17.80 b
2. tunnel 1000 ppm	29.00a	37.35a	15.66 b	28.37a	42.65a	23.61a
3. tunnel control	28.36a	36.02a	15.21 b	24.51a	35.59a	15.15 b
3. tunnel 700 ppm	31.06a	39.52a	19.45 ab	26.63a	41.45a	22.04 ab

* Numbers followed by the same letter within a column are not significantly different according to Tukey's test (P>0.05).

Table 4. pH, total soluble solid content and acidity values from tunnels enriched by CO_2

	2007			2008		
Application	pH	Soluble solid content	Titratable acid	pH	Soluble solid content	Titratable acid
1. tunnel control	3.86a*	7.75a	0.86a	3.92a	8.00a	0.69a
1. tunnel 500 ppm	3.90a	7.50a	0.83a	3.92a	8.08a	0.65a
2. tunnel control	3.84a	7.50a	0.95a	3.95a	8.16a	0.74a
2. tunnel 1000 ppm	3.86a	7.60a	0.82a	3.92a	8.25a	0.72a
3. tunnel control	3.90a	7.50a	0.93a	3.95a	8.00a	0.73a
3. tunnel 700 ppm	3.88a	7.75a	0.91a	3.97a	9.00a	0.71a

* Numbers followed by the same letter within a column are not significantly different according to Tukey's test (P>0.05).

Table 5. Effect of CO2 application on Strawberry Fruit Firmness

Application	Fruit firmness (lb)
1. tunnel control	0.83 c*
1. tunnel 500 ppm	1.02 b
2. tunnel control	0.84 c
2. tunnel 1000 ppm	1.24 a
3. tunnel control	0.85 c
3. tunnel 700 ppm	1.56 a

*Means followed by different lower case letters are significantly different (P< 0.05)

strawberry has no effect to reduce *T. cinnabarinus* populations does not mean that the same applies for other pests. That's why, encouragement of CO_2 applications is of great benefit using further studies against pests due to their contributions to yield and quality parameters in strawberry.

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